Information Summary

National Aeronautics and Space Administration

Shuttle launch imagery from land, air and water

Additional cameras during launch give more detail

The Vision for Space Exploration is being made a reality at Kennedy Space Center in Florida through the Space Shuttle Program. KSC is taking the word "vision" literally.

Eyes around the world watch the spectacle of Space Shuttle launches. But the eyes of NASA are on the close-up details, which they see thanks to the addition of more cameras.

This long-range tracking telescope on Playalinda Beach, north of KSC, uses two lenses: on top, a 400-inch lens for 35-mm film, and on the bottom, a 200-inch lens for video.

When the Space Shuttle returned to flight in 2005, more cameras examined its ascent than ever in the past. The reason was a major improvement in the tracking and imaging capabilities at Kennedy Space Center, primarily through additional cameras and digital resolution, as recommended by the Columbia Accident Investigation Board in its report released in July 2003.

Cameras are either fixed or mounted on a tracker. A variety of trackers are used at the different camera sites, the predominant tracker being a Kineto Tracking Mount (KTM) tracker. All of the trackers within close proximity to the launch pads are remotely controlled. The remaining trackers are remotely or manually controlled on site.

Cameras at KSC are sited for short-range tracking (T-10 through T+57 seconds), medium-range (T-7 through T+110 seconds), and long-range (T-7 through T+165 seconds) during a launch. Around the launch pad, cameras focus on the External Tank, Solid Rocket Boosters and Orbiter. For miles up and down the coast, tracking cameras and long-range optical tracking systems capture ascent imagery.

Before 2003, four **short-range tracking cameras** on two sites were used on the launch pads, on camera sites two (east side) and six (northwest) (*see p. 3*). Remotely controlled from the Launch Control Center, one camera focused on the top half of the Shuttle and one focused on the bottom half.

Cameras on site six view the hydrogen vent arm (above the External Tank) as it releases and also views the underside of the orbiter's left wing. Cameras on site two view the area between the orbiter and the External Tank to see any debris or ice that might fall.

For Return To Flight, there are three camera sites: one, two and six. Two new cameras have been added for camera site one, which is northeast. The addition of this tracker ensures a view of the underside of the right wing, as well as the area between the External Tank and the orbiter to track any debris during its roll maneuver. All camera sites have two film cameras and one High Definition Television (HDTV) video camera.

The short-range tracking cameras have 200mm (focal length) lenses, running 100 frames per second (fps). Each camera is loaded with 400 feet of film.

In addition to the film cameras around the launch pads, there are 42 fixed cameras with 16mm motion picture film.

Medium-range trackers are located at six sites along the coast and near the Launch Complex 39 Area. Placement at these sites provides three views for triangulation, to better characterize any suspect area. *(See p. 3)*

These cameras have 800mm (32-inch) and greater lenses (80-inch and 120-inch), running 100 feet per second. Three of the cameras have 400 feet of film, two of the cameras have 1,000 feet. The additional tracking cameras have 150-inch lenses, with 1,000 feet of film.

The 10 sites also have HDTV video cameras.

Long-range cameras are used during early phases of ascent to identify and track debris and continue to be used as long as the vehicle is visible.

Long-range trackers are located at 11 sites north and south of the pads, ranging approximately 38 miles north to Ponce Inlet and 23 miles south to Patrick Air Force Base (PAFB) *(see p. 4)*.

One camera is mobile, an Advanced Transportable Optical Tracking System (ATOTS) on north Merritt Island.

Two of the cameras are part of the Distant Object Attitude Measurement System (DOAMS), located at Playalinda Beach and Cocoa Beach. A refurbished five-meter focal length telescope was recently installed in the Cocoa Beach location. Each of these camera sites will also have HDTV video cameras.

A unique feature of the tracking telescopes is a robotic camera manned by a technician sitting on top and gently manipulating a joystick to map the Shuttle's trek through the sky.

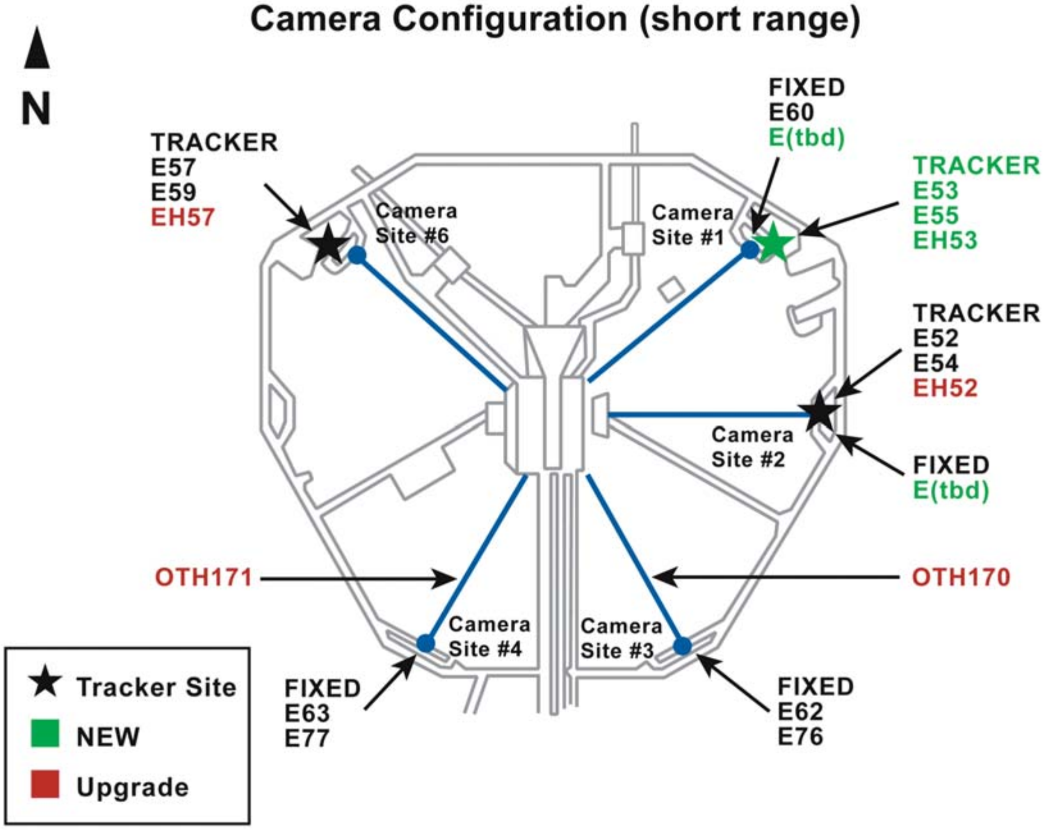
"The joystick is so sensitive, it even responds to the heartbeat of the person using it," explains Bob Page, chairman of the NASA Intercenter Photo Working Group.

There are two lenses stacked vertically. The top is a 400-inch lens for 35mm film. The bottom is a 200-inch lens for video.

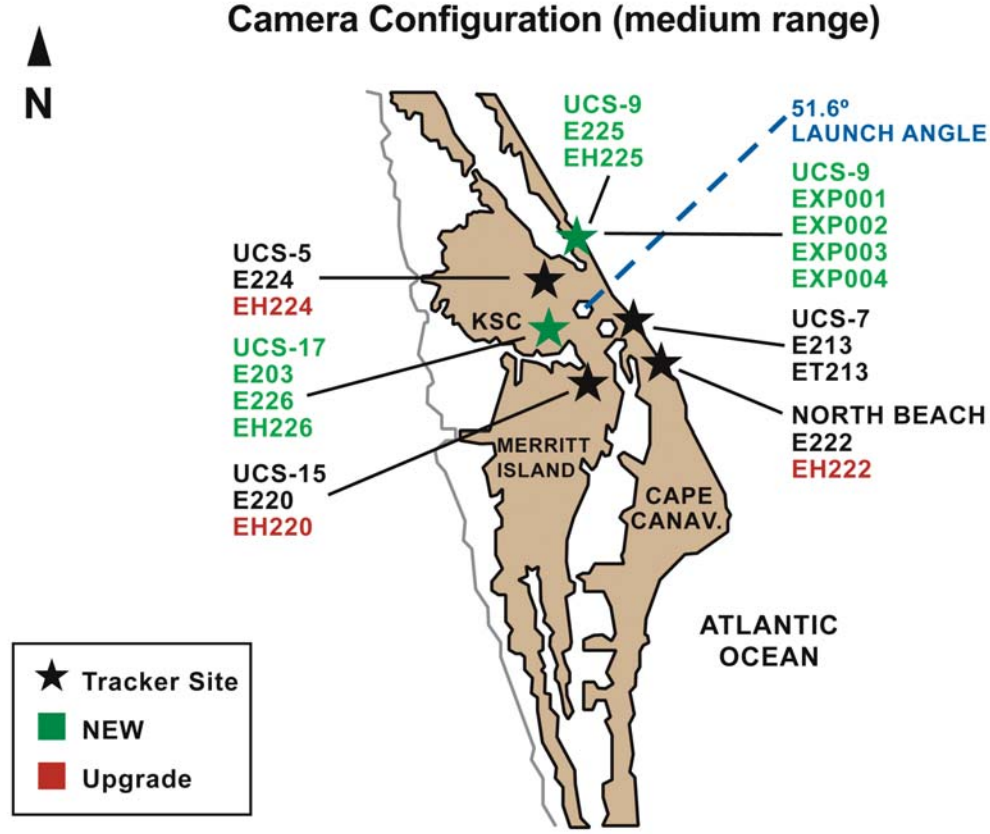
Improvement in backup imagery is a change from the standard analog video camera (640 x 480 resolution at 30 fps interlaced) to a digital high-definition camera (1280 x 720 resolution at 60 fps progressive).

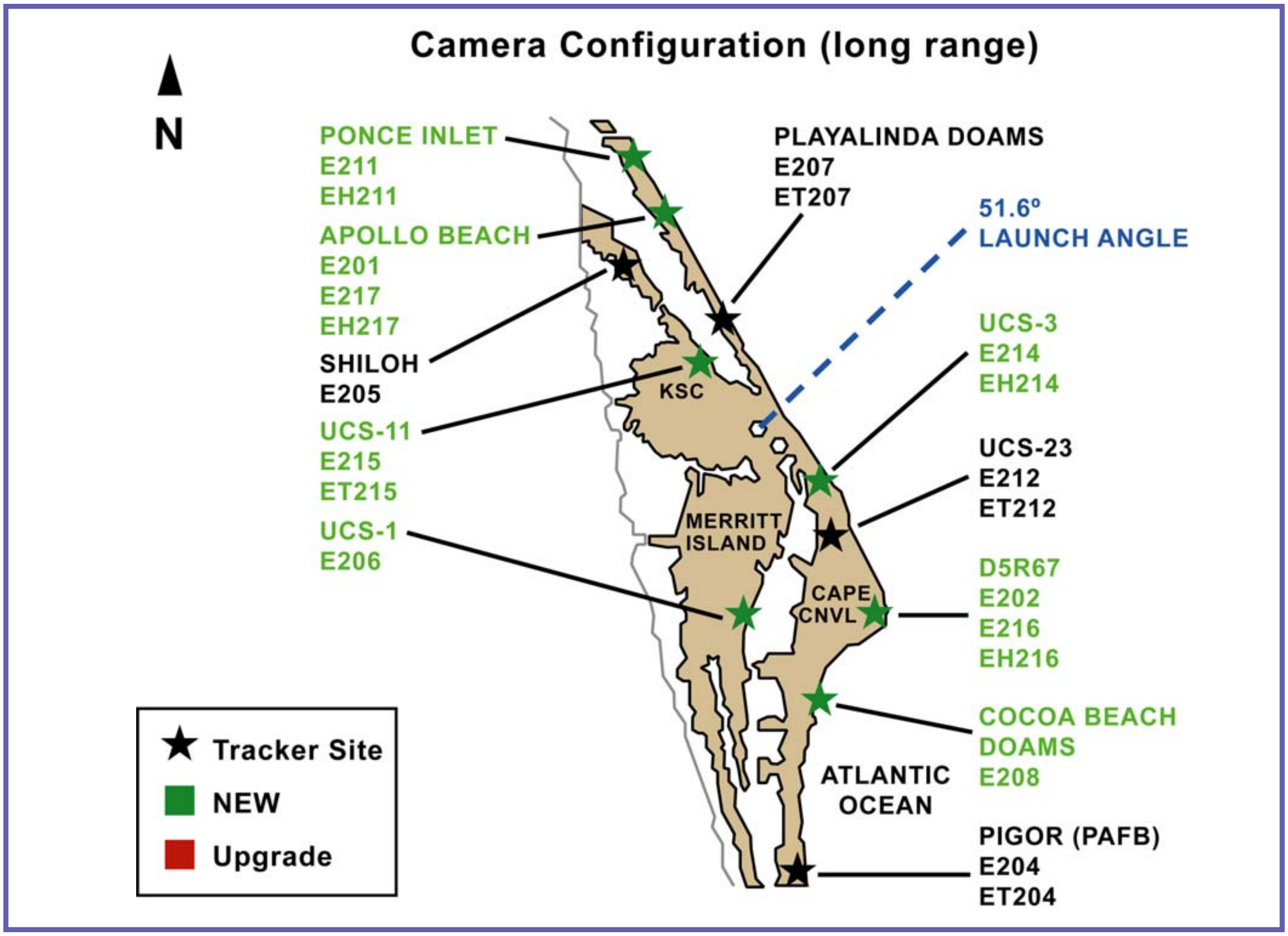
Ten of these Contraves-Goerz Kineto Tracking Mounts (KTM) are certified for use on the Eastern Range. They include a two-camera, camera control unit offering a combination of film, shuttered and high-speed digital video, and FLIR cameras configured with 20-inch to 150-inch focal length lenses.

Camera Configuration (short range)



Camera Configuration (medium range)





Statistics

Total No. Cameras	84
Land-Based Camera Sites	20
Long-Range Tracking Sites (T-165 seconds)	11
Long-Range Cameras	21
Medium-Range Tracking Sites (T+110 seconds)	6
Medium-Range Cameras	17
Short-Range Tracking Sites (T+57 seconds)	3
Short-Range Cameras	9
Launch/Perimeter Cameras	37

Other Camera Locations

Launch Pad

Ascent ground cameras also provide imagery from the **Mobile Launch Platform** (MLP) and on the **Fixed Service Structure** (FSS). Twenty-two 16mm cameras are on the MLP and eight 16mm cameras are on the FSS.

Radar Tracking

A new wideband and Doppler radar tracking system has been implemented for adequately detecting debris during launch and ascent. Three radars will digitally record tracking data of the Shuttle from launch until the signal is lost, with the primary timeframe of interest being launch plus 60 seconds to launch plus two minutes.

The three radar systems include one C-band and two Doppler X-band.

The Wideband Coherent C-band Radar provides high spatial resolution of debris events and can detect them within the Shuttle vehicle stack.

The radar resides in an area in the northern part of Kennedy Space Center.

The two Weibel Continuous Pulse Doppler X-band radars are located on ships, one mounted on a booster recovery ship downrange of the launch site and the other on a ship south of the ground track. The two radars provide velocity and differential Shuttle/debris motion information.

The radar data will be analyzed at the NCAR site. The C-band data will be available in near real-time, while the X-band data (screen captures) will be sent from the ships via satellite link to the NCAR site.

The southern ship is expected back in port six hours after launch, and the data will be transported immediately to the NCAR site.

At Hangar AF at Cape Canaveral Air Force Station, workers on the Liberty Star, one of the two SRB Retrieval Ships, oversee the safe placement of an X-band Doppler radar array onto the deck. The radar will be used for tracking support on NASA's Return to Flight mission, STS-114, on Space Shuttle Discovery.

Shuttle-Based Camera Views

New and modified cameras on the Space Shuttle Discovery, Solid Rocket Boosters and External Tank will greatly increase the views available to verify the health of the Shuttle's Thermal Protection System and the redesigned portions of the Exernal Tank, and to verify there is no hazardous debris or damage during ascent.

Previously used cameras on the boosters were reinstated to provide views of the External Tank intertank for Return to Flight mission STS-114. The cameras are located below the nosecone of each booster. Their imagery is recorded for playback after the booster retrieval from the Atlantic Ocean.

A television camera installed on the exterior of the External Tank was repositioned to a point several feet above the right bipod area in the liquid oxygen feedline fairing housing.

The new site provides greater visibility of the Shuttle's underside and tank.

A 35mm still camera that was located in the right umbilical well on the underside of the orbiter on previous Shuttle flights was replaced with a Kodak DCS760 digital still camera.

The new camera takes digital images of the tank after it has separated from the orbiter and feeds them to a laptop computer in the crew cabin. The crew then downlinks those images to Mission Control for analysis early in the flight.

The left umbilical well continues to have two film cameras to gather movie imagery for use in analysis after it has been returned to Earth.

Handheld cameras used by crew members have been modified to allow them to take digital images that can be processed onboard the Shuttle as well as transmitted to the ground.

These enhancements are part of a project known as the Enhanced Launch Vehicle Imaging System (ELVIS).

On Return to Flight mission STS-114, a new handheld digital camera and flash were made available to astronauts to take electronic images of exterior surfaces of the Shuttle during spacewalks.

The new Extravehicular Activity (EVA) camera is a Kodak DCS760, the same used for digital imagery inside the Shuttle cabin. Some modifications were made to equip it for use in the vacuum and extreme temperatures of space: a change of lubricants for the camera and a thermal protective covering.

In addition, the flash was modified to remain in an air-tight housing for use in the vacuum of space.

Digital images taken during a spacewalk are stored in the memory of the camera and later brought back inside the Shuttle cabin. They are then fed into a laptop computer in the cabin and transmitted to Mission Control.

The digital EVA camera may be used to provide images of an inflight repair performed during a mission, to assist an EVA inspection of potential damage or for other reasons.

Cameras

A variety of cameras and lenses are used to support ascent imaging, including film and digital cameras:

- 35mm film cameras used at the pad and on short-, medium- and long-range camera sites provide the highest resolution. They are the primary imagery as they meet the minimum size requirements for debris identification during ascent.

- HDTV digital video cameras are co-located with many of the 35mm cameras and provide quick-look capability. The digital video data enables speedy post-launch imagery processing and review (quick-look) before the film is processed and distributed.

- The National Television Standards committee provides backup for sites without HDTV.

- 70mm motion picture film cameras provide "big sky" views.

- 16mm motion picture film cameras are used on the Mobile Launch Platform and Fixed Service Structure of the launch pad.

Other cameras are located throughout the launch pad perimeter and other locations, providing additional quick-look views of the launch.

Aircraft provide additional views of the Space Shuttle during ascent

NASA has approved the development and implementation of an aircraft-based imaging system. The WB-57 Ascent Video Experiment (WAVE) was to be used on an experimental basis during the first two Space Shuttle launches for Return to Flight.

The WAVE provides both ascent and entry imagery and enables better observation of the Shuttle on days of heavier cloud cover and areas obscured from ground cameras by the launch exhaust plume.

WAVE comprises a 32-inch-ball turret system mounted on the nose of two WB-57 aircraft. The turret houses an optical bench, providing installation of both HDTV and infrared cameras. Optics consist of an 11-inch-diameter, 4.2 meter fixed-focal-length lens. The system can be operated in both auto track and manual modes.

The two imaging cameras are an HDTV color camera (Panasonic AK-HC900) and a Near Infrared camera (Sensors Unlimited SU640SDV 1.7RT/RS-170). Both share a Celestron fixed field-of-view telescopic lens. In addition, a National Television Standards Committee color acquisition camera were used to track the Shuttles during ascent on both Return to Flight missions.

The aircraft took off from Patrick Air Force Base approximately two-and-a-half hours before launch and entered a holding pattern: one north of the Shuttle's flight path and one south.

The aircraft communicated with a WAVE Operations Officer in the Range Operations Control Center, who in turn communicated with the chairperson of the imagery team in the Launch Control Center.

NASA has approved the development and implementation of an aircraft-based imaging system, using NASA's WB-57 aircraft (above). The WB-57 Ascent Video Experiment (WAVE) was used on an experimental basis during the first two Space Shuttle flights following Return to Flight in 2005.

The two aircraft, flying at an altitude of 60,000 feet, allow a wide range of coverage, with each plane providing imagery over a 400-mile path.

The entry imaging program also proposed using additional aircraft to provide imagery during later stages of entry.

If the WAVE system performance and quality of images are acceptable, relevant and valid, NASA will consider use of this system on future flights.

NASA's Johnson Space Center operates the only two WB-57s still flying in the world today, out of Ellington Field, Houston, Texas. Identified as NASA 926 and NASA 928, the high-altitude weather aircraft can fly day and night with a range of approximately 2,500 miles.

Two crew members in pressurized suits pilot the plane to altitudes in excess of 60,000 feet and the aircraft can carry a payload of about 6,000 pounds.

On Aug. 10, 2001, Space Shuttle Discovery hurtles into the blue sky from Launch Pad 39A on mission STS-105.

NASA: Explore. Discover. Understand.